Impact of GNSS Orbit Modeling on Reference Frame Parameters

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Outline

Introduction / the ECOM

Problems with the ECOM

Extending the ECOM

Results with the new ECOM

Conclusions

Orbit modeling

- Every satellite method of space geodesy has to determine orbit parameters of the observed satellites when solving for global parameters of geophysical interest (geocenter, Earth rotation parameters, ...)

  $\longrightarrow$ Orbit modeling deficiencies map into parameters!
- Most important non-gravitational force: Solar radiation pressure (SRP). Causes orbital perturbations of $\sim$100 m after one revolution.
- A priori SRP modeling: E.g. ROCK models for GPS, or box-wing models
- Empirical SRP modeling: Estimate appropriate empirical accelerations. E.g. **ECOM**.

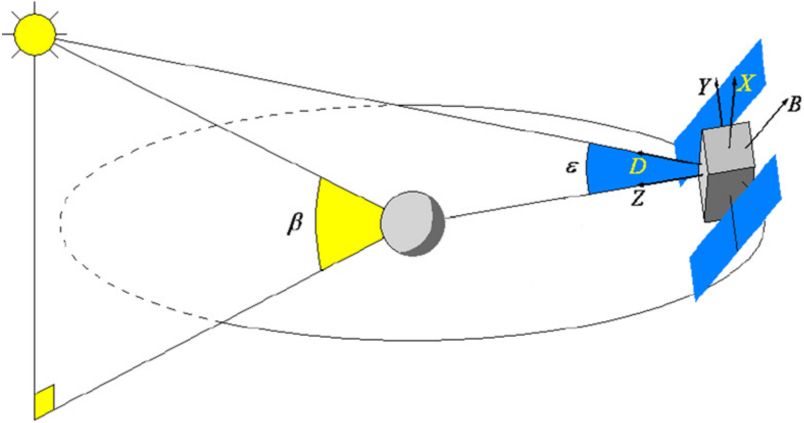
The ECOM

CODE: Center for Orbit Detrmination in Europe

Empirical CODE Orbit Model (ECOM, Beutler et al., 1994):

- Motivated by the lack of reliable satellite information and the concern that estimating a scaling factor for the ROCK models is not sufficient
- Decompose perturbing accelerations into three orthogonal directions suitable for SRP modeling

The ECOM (2)



The ECOM (3)

A priori model

Argument of latitude

$$\vec{a} = \vec{a}_0 + D(u)\vec{e}_D + Y(u)\vec{e}_Y + B(u)\vec{e}_B\,,$$

The ECOM (3)

$$\vec{a} = \vec{a}_0 + D(u)\vec{e}_D + Y(u)\vec{e}_Y + B(u)\vec{e}_B\,,$$

$$\begin{aligned} D(u) &= D_0 + D_c \cos u + D_s \sin u \\ Y(u) &= Y_0 + Y_c \cos u + Y_s \sin u \\ B(u) &= B_0 + B_c \cos u + B_s \sin u\,, \end{aligned}$$

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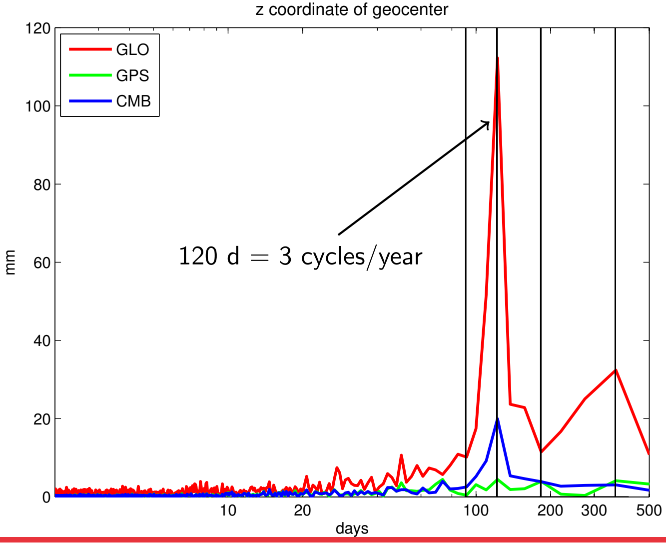
5-parameter ECOM, widely and successfully used for the last 20 years. At CODE since mid 2013 without a priori model $\vec{a}_0$.

Problems with the ECOM

Traditional ECOM shows deficiencies when applied to GLONASS:



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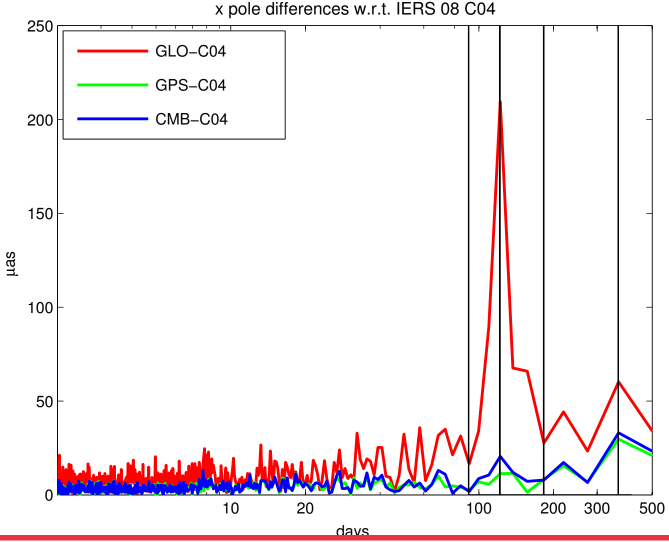
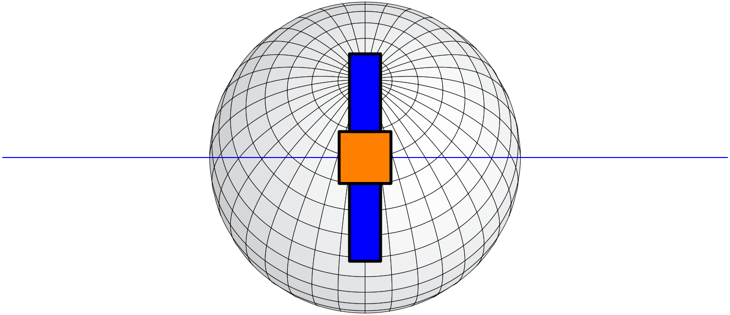


Problems with the ECOM

- GLONASS induces huge artifacts in time series of geodynamical and reference frame parameters
- Meindl et al., 2013 explained mechanism how this could be introduced into geocenter results
- Rodríguez-Solano et al., 2014 traced back the problems to the ECOM: Using an adjustable box-wing model significantly reduces the spurious signals

$\longrightarrow$ Revise ECOM!

Observing GLONASS satellite from Sun ($\beta = 0^\circ$)



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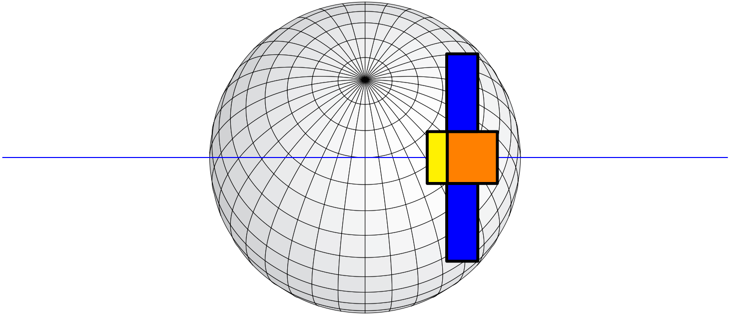

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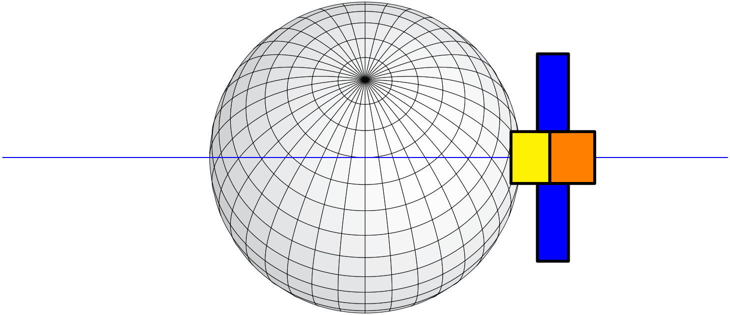

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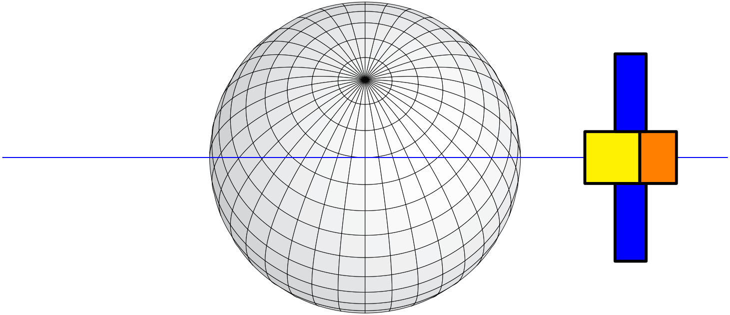

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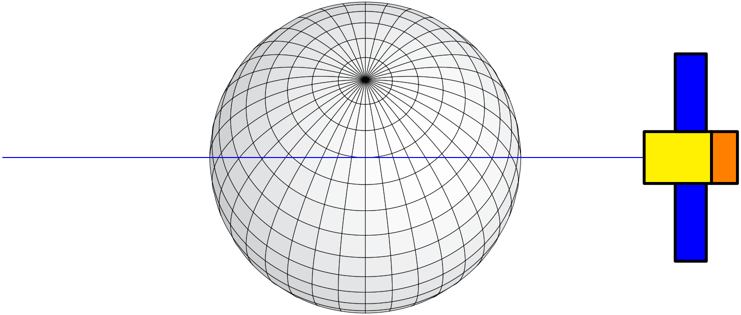

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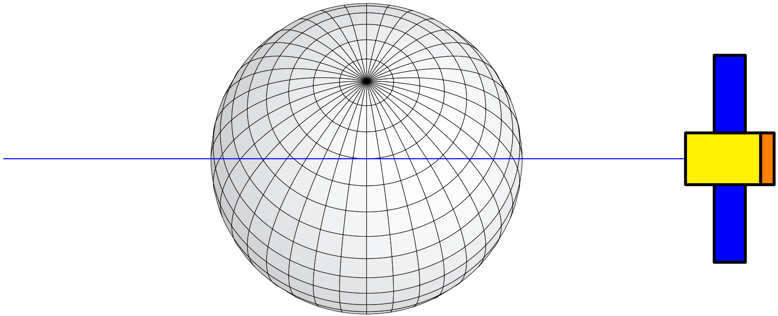

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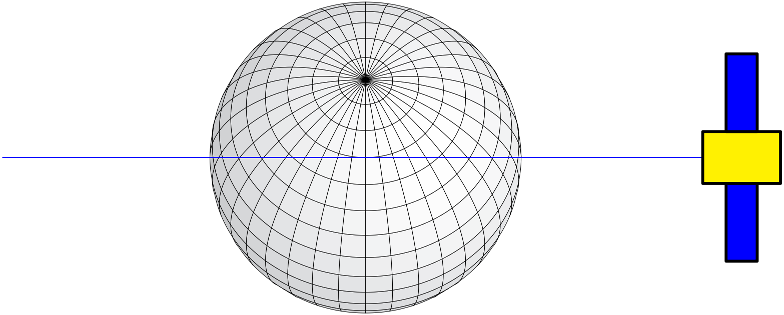

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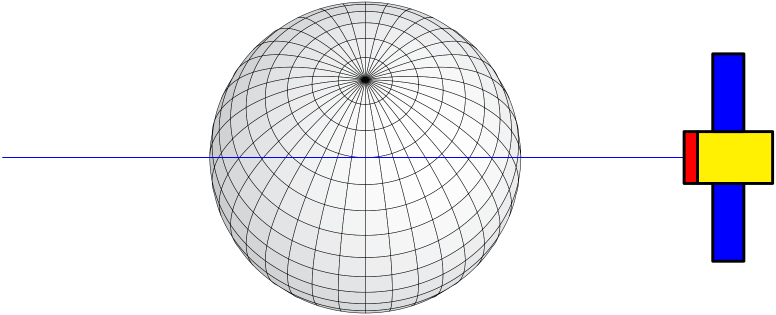

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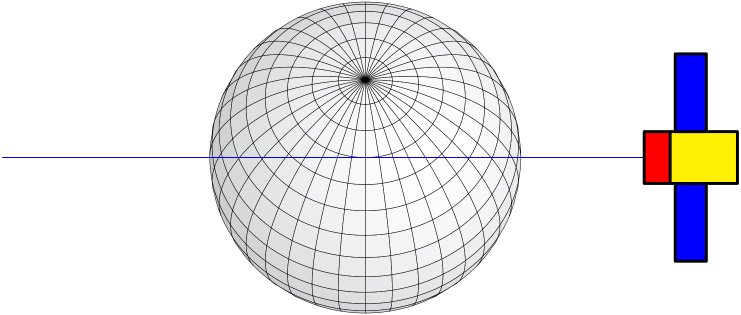

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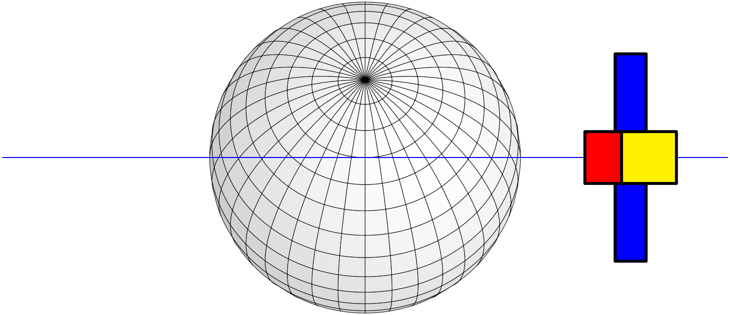

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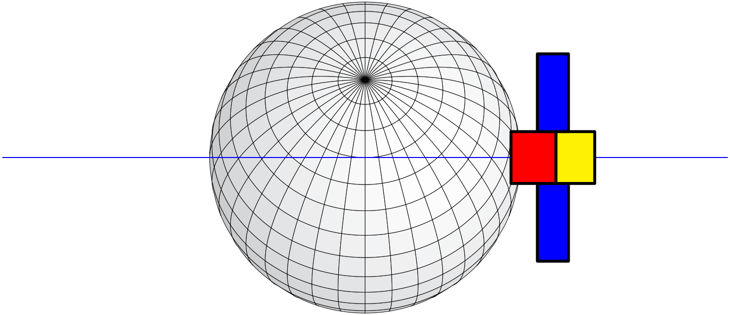

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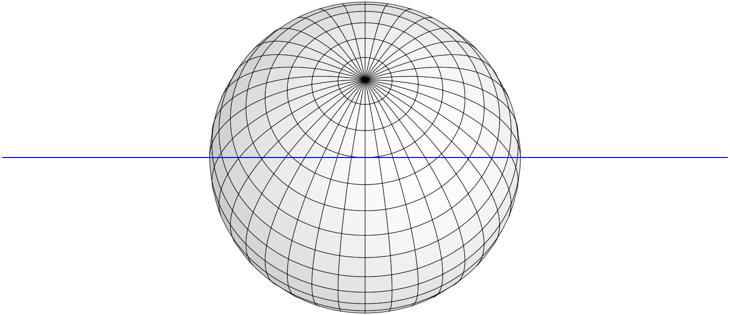

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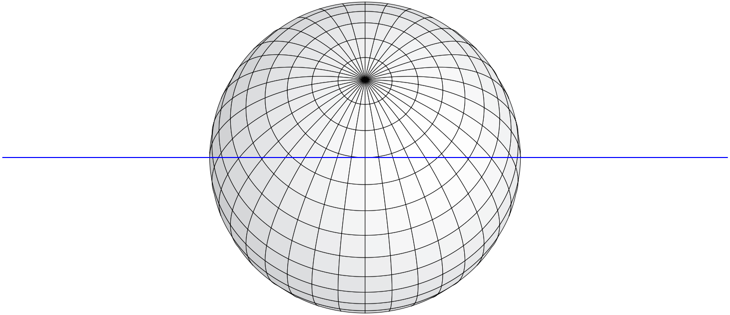

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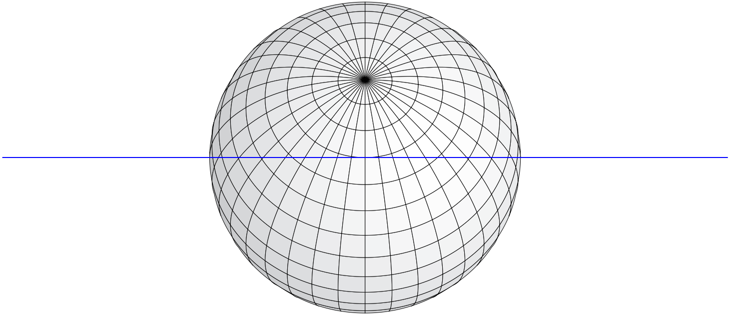

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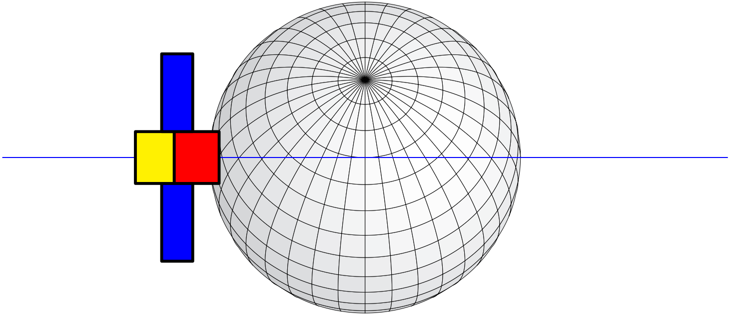

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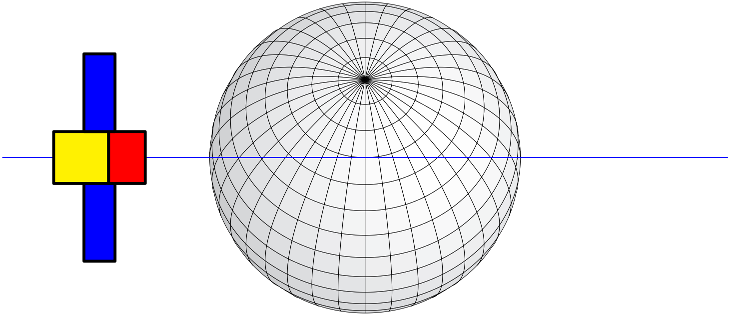

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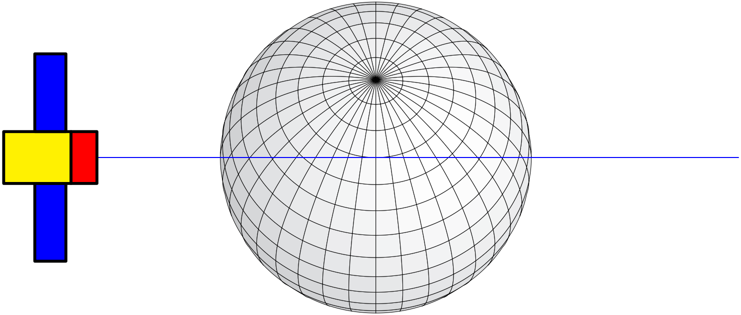

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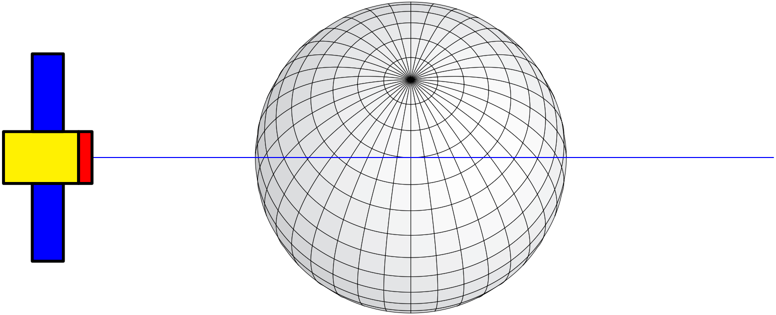

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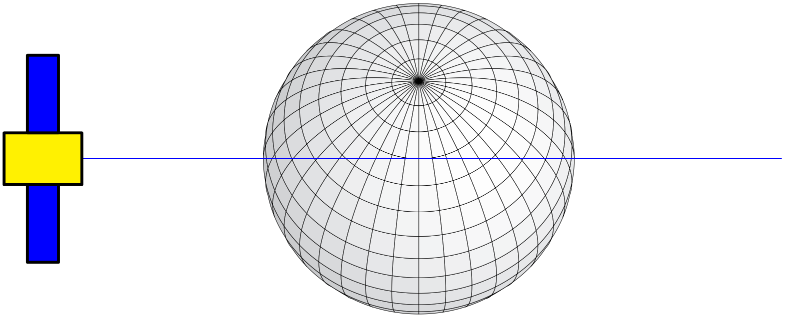

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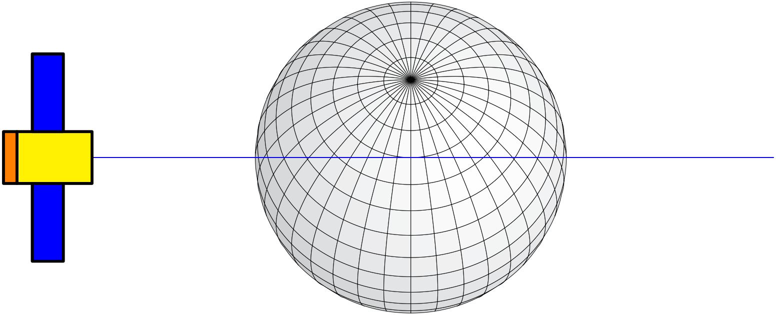

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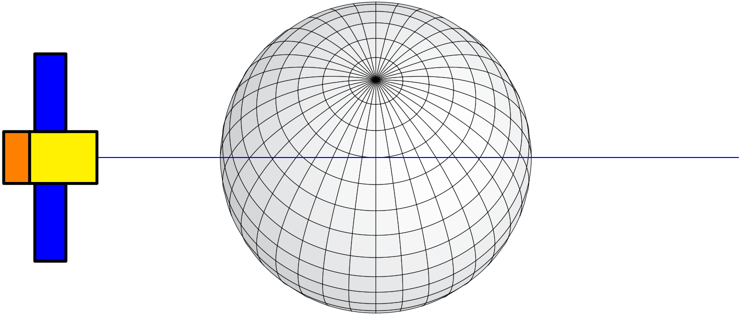

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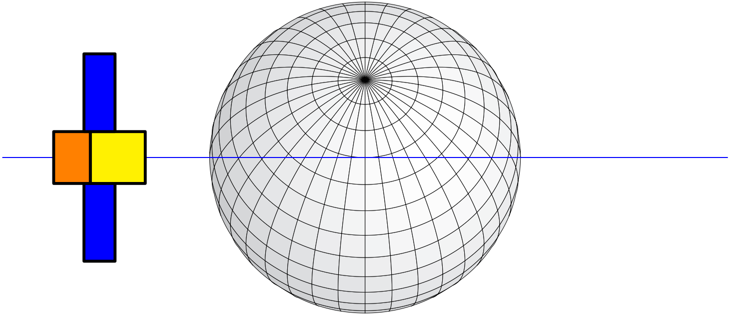

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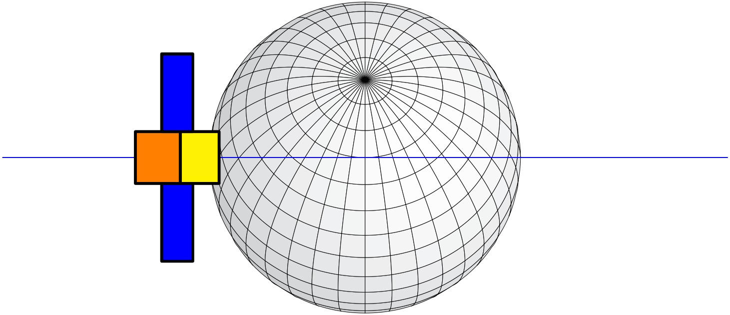

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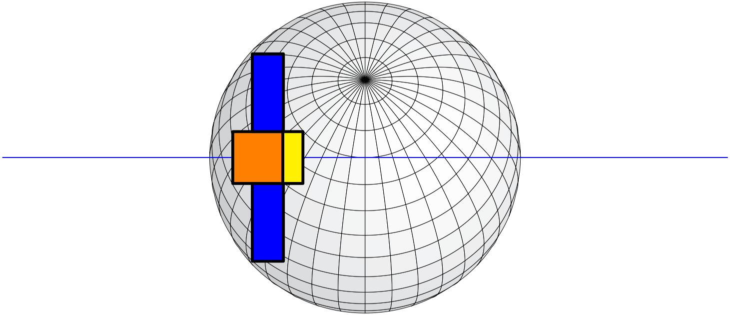

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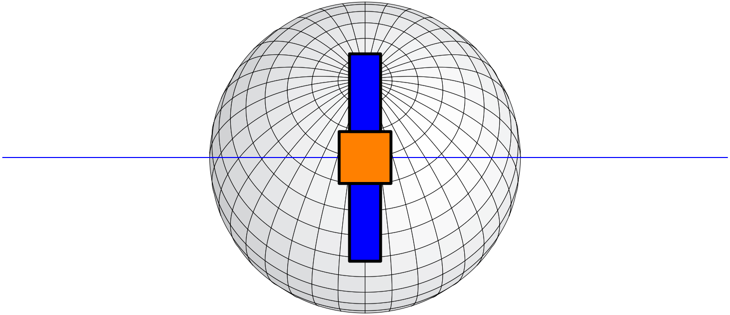


Extending the ECOM

- Solar panels are (ideally) always perpendicular to $\vec{e}_D$ and only cause a (large) contribution to D_0.
- For elongated satellite bodies (like GLONASS), the periodic D-terms must not be negected!
- The periodic terms become more important for low β-angles
- **For perfect yaw-steering attitude of a satellite with symmetric surface propierties**:
  - D-terms: D_0, D_2, D_4,...
  - B-terms: B_1, B_3, B_5,...
- A Sun-fixed angular argument is more appropriate for interpretation of estimated ECOM parameters. Use

$$\Delta u \doteq u - u_s$$

where u_s is the argument of latitude of the Sun.

Extending the ECOM

$$D(u) = D_0$$

$$Y(u) = Y_0$$

$$B(u) = B_0 + B_{1,c}\cos(u) + B_{1,s}\sin(u)$$

Extending the ECOM

$$D(u) = D_0 + D_{2,c}\cos(2\Delta u) + D_{2,s}\sin(2\Delta u) + D_{4,c}\cos(4\Delta u) + D_{4,s}\sin(4\Delta u) + \ldots$$

$$Y(u) = Y_0$$

$$B(u) = B_0 + B_{1,c}\cos(\Delta u) + B_{1,s}\sin(\Delta u) + B_{3,c}\cos(3\Delta u) + B_{3,s}\sin(3\Delta u) + \ldots$$

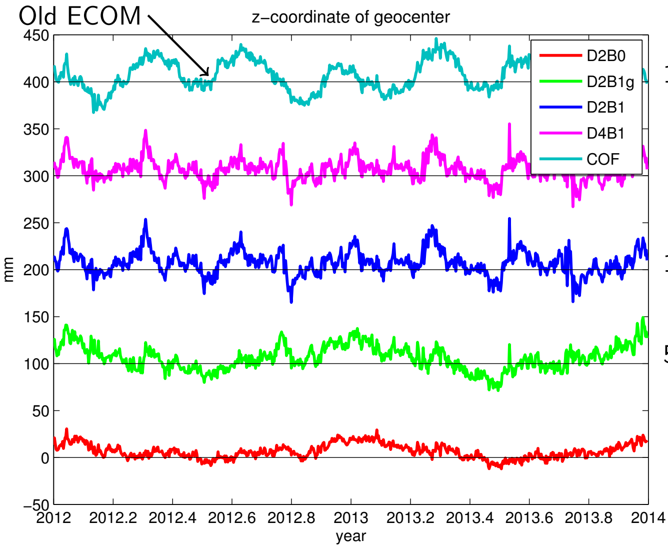
The new ECOM

Different parametrizations were extensively tested using as quality measures

- Geocenter coordinates,
- ERPs,
- Station coordinates,
- Satellite orbits,
- SLR validation of satellite orbits.

Sol	D_2	D_4	B_1	# par
D2B0	yes	no	no	5
D2B1g	yes	no	GPS	5(GLO), 7(GPS)
D2B1	yes	no	yes	7
D4B1	yes	yes	yes	9
COF (D0B1)	no	no	yes	5

The new ECOM



Ampl. at 3/1 cpy:

18/9 mm

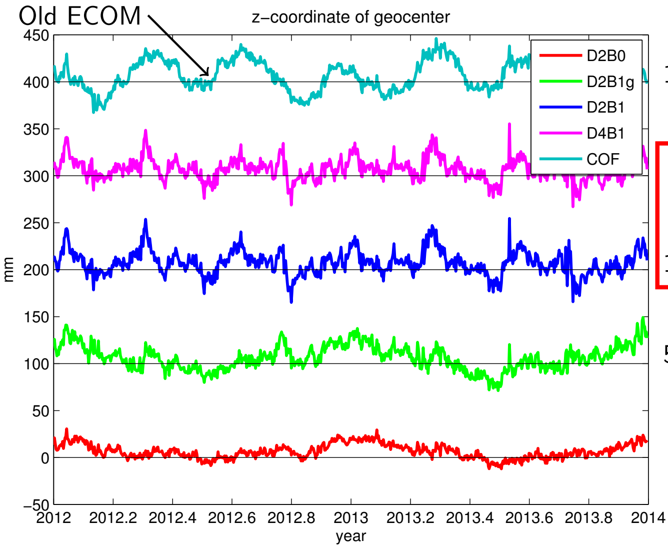
8/4 mm

10/4 mm

5/14 mm

3/8 mm

The new ECOM



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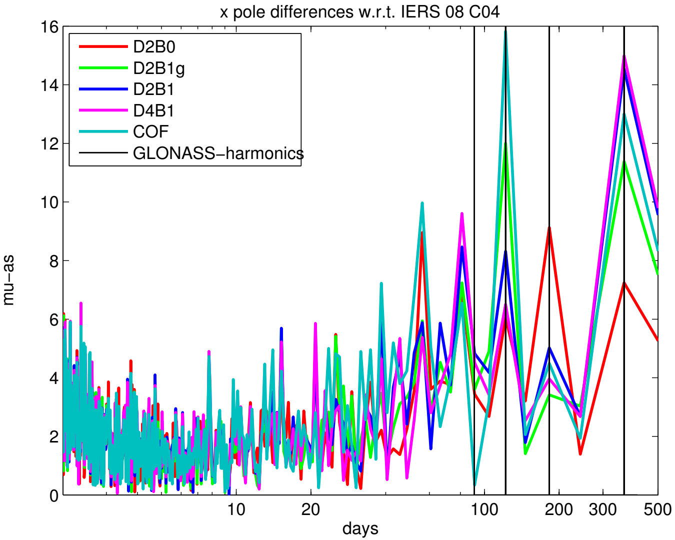
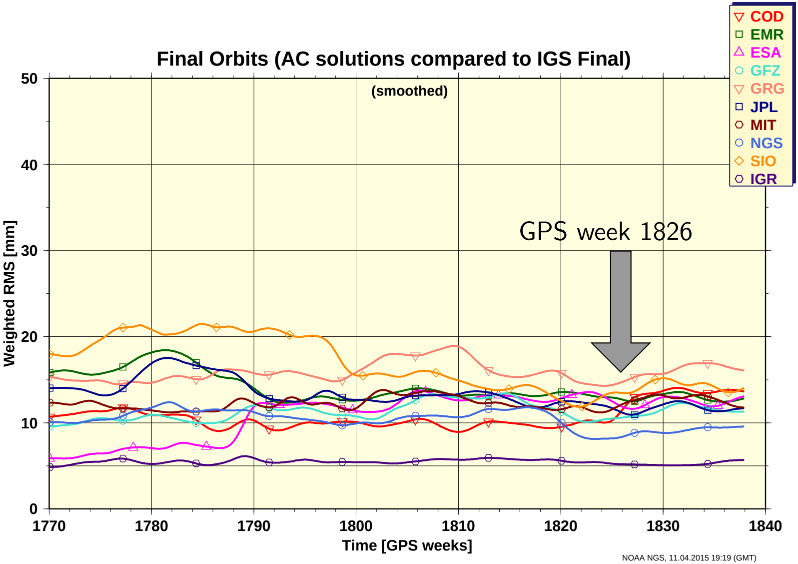

x pole differences w.r.t. IERS 08 C04
D2B0
D2B1g
D2B1
D4B1
COF
GLONASS−harmonics
mu−as
days
0
2
4
6
8
10
12
14
16
10
20
100
200
300
500

Conclusions

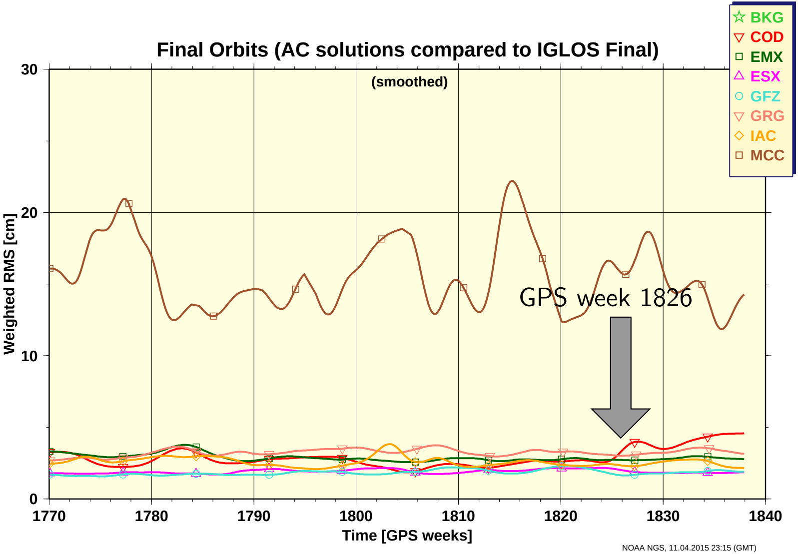
- The classic ECOM performs well for GPS, but must be extended by even-order periodic D-terms when applied to elongated satellite bodies (e.g. GLONASS, Galileo). Significant reduction of GLONASS-induced spurious signals.
- CODE IGS contributions based on D4B1 model since January 4, 2015 (GPS week 1826)
- For impact of extended ECOM on multi-GNSS orbit and clock solutions: see presentation of **Lars Prange on Thursday, 14:00, in Session G1.3, room G12**.
- See "CODE's new solar radiation pressure model for GNSS orbit determination", accepted for publication at J. Geod., DOI: 10.1007/s00190-015-0814-4

Thank you

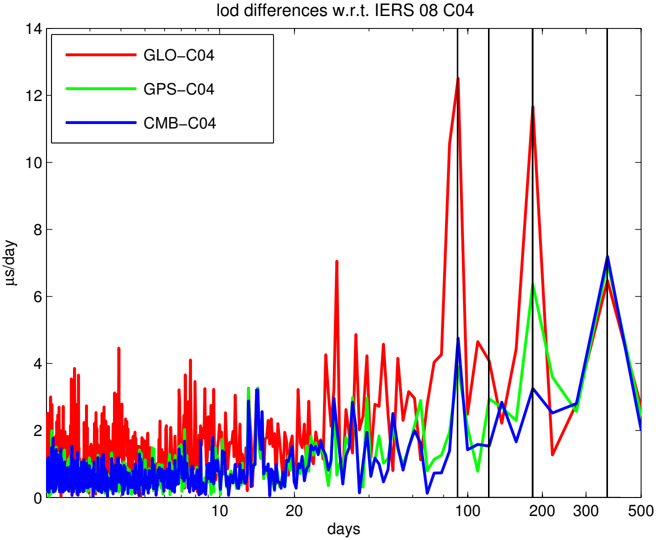
Consistency with other solutions (GPS)



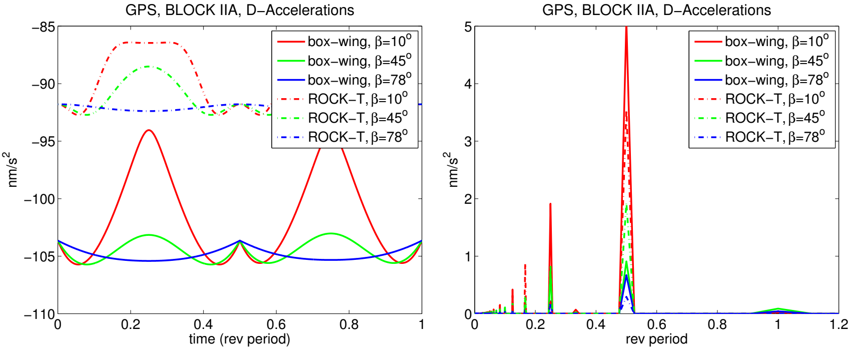
Consistency with other solutions (GLONASS)



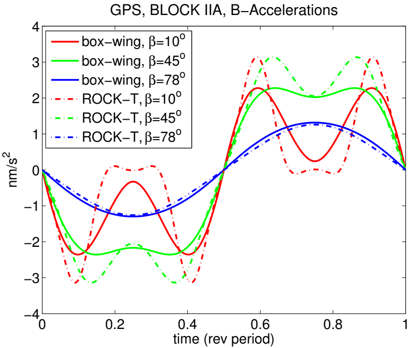
Problems with the ECOM

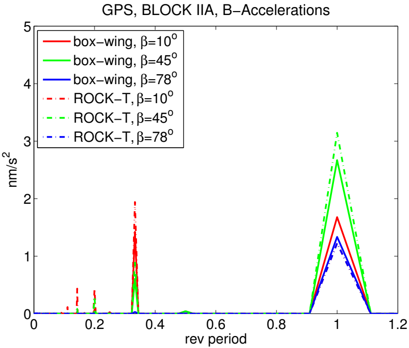


ROCK and BW accelerations for GPS (D)

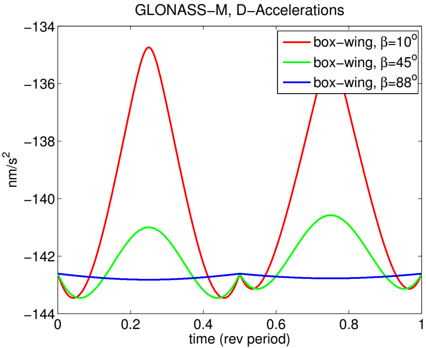


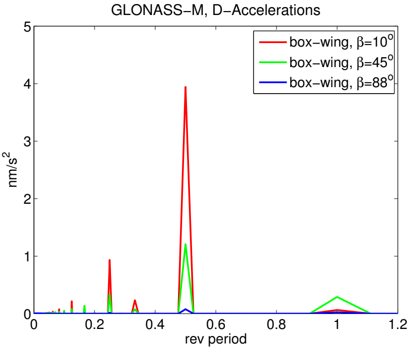
ROCK and BW accelerations for GPS (B)



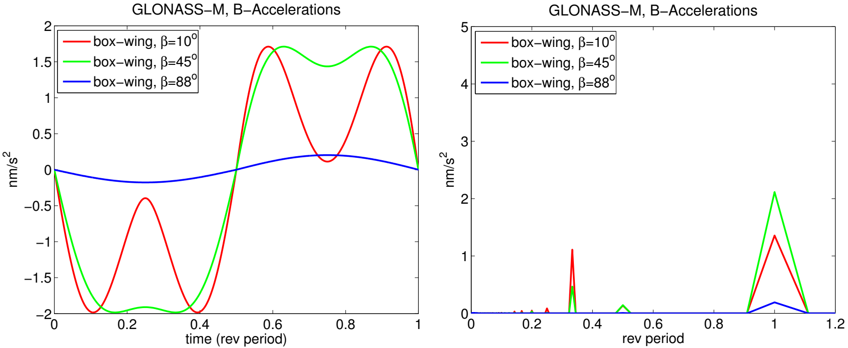


BW accelerations for GLONASS (D)



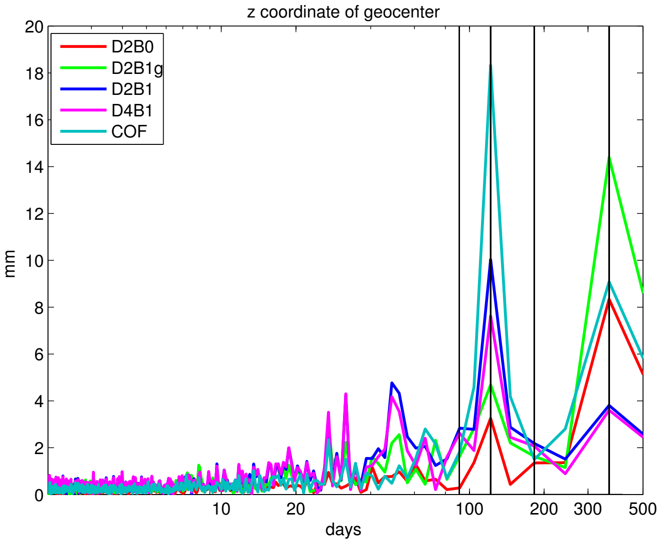


BW accelerations for GLONASS (B)



Daniel Arnold: Impact of GNSS Orbit Modeling on Reference Frame Parameters
EGU General Assembly, 15 Apr 2015

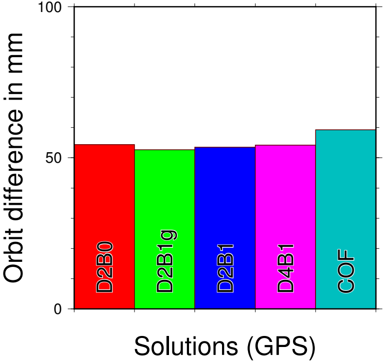
Geocenter

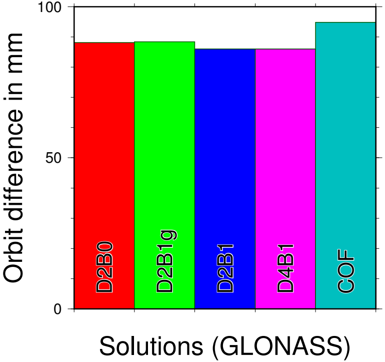


z coordinate of geocenter
D2B0
D2B1g
D2B1
D4B1
COF
mm
20
18
16
14
12
10
8
6
4
2
0
10
20
100
200
300
500
days

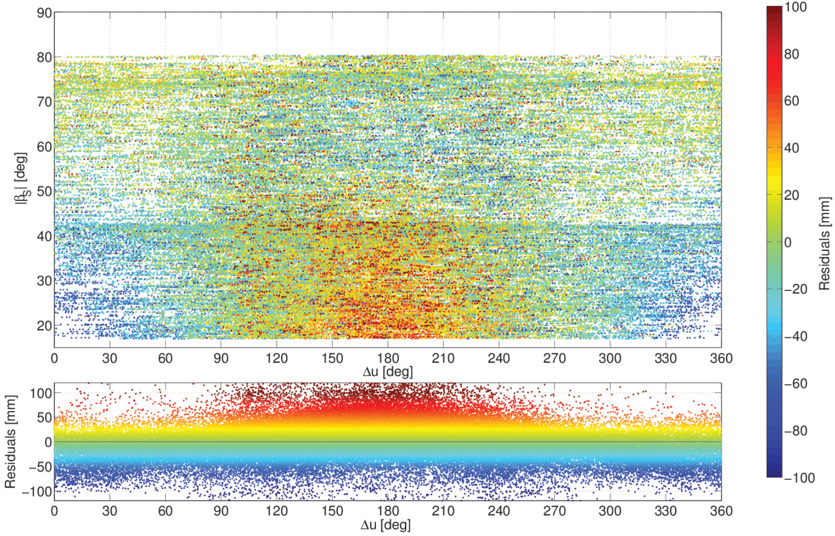
Orbits

Mean 3-dimensional orbit misclosures at day boundaries





SLR residuals of GLONASS (COF)



SLR residuals of GLONASS (D2B1)